METRO Green Line Transit Signal Priority: Implementation and Lessons Learned

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The METRO Green Line (formerly Central Corridor LRT) is the region's second light rail line. It links five major centers of activity in the Twin Cities region: downtown Minneapolis, the University of Minnesota, the Midway area, the State Capitol complex and downtown St. Paul. The Central Corridor area is a highly built-up urban environment that imposes different planning and operational challenges than the Blue Line, the region's first light rail line, which operates in less densely developed areas for much of its length.

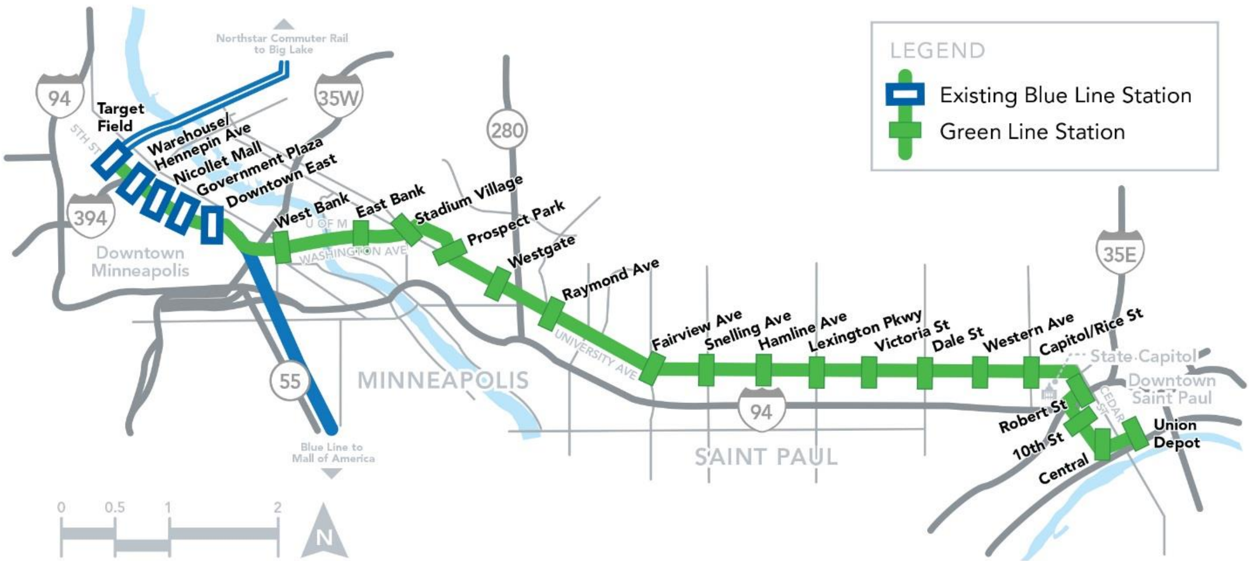

Figure 1. METRO Green Line Route and Stations.

The Green Line has consistently exceeded ridership projections since it entered passenger service in June 2014, with more than six million rides in the line's first six months of operation. Average weekday ridership in November 2014 was 36,240, not far off the 41,000 rides projected for 2030.

Much of the Green Line route is in dedicated right of way in the center of University Avenue, a major east-west street between St. Paul and Minneapolis. This busy commercial corridor has high volumes of pedestrian traffic and is crossed by major arterial streets. Green Line trains pass through 68 traffic signals along the length of the alignment, with typical signal spacing of 300 feet in the downtown areas and one-quarter mile along University Avenue.

When the Green Line opened in June 2014, the line's scheduled end-to-end run time of 48 minutes was based on a goal of no more than eight minutes of total signal delay, which equates to an average of less than eight seconds of delay per signal. The number of traffic signals that the Green Line must travel through, combined with the 48-minute schedule, makes transit signal priority (TSP) critical to reliable, on-time service. Operating behind schedule not only impacts customer experience and satisfaction, it also results in additional operating costs when additional light rail vehicles must be introduced to maintain acceptable service frequency. Transit signal priority also provides opportunities for schedule recovery after minor disruptions.

Metro Transit faced several technical challenges in implementing TSP along the Central Corridor:

- The large number of closely spaced traffic signals include many intersections that have low traffic volumes on the cross streets;
- As required by the local agency, signal timing with TSP must serve all phases, maintain coordination, and provide pedestrian crossings every cycle, resulting in an available TSP time of roughly 10 seconds;
- Both LRT and street traffic need two-way progression;
- If a train falls behind the signal coordination band, it will continue to fall further behind schedule at the downstream signals, until it can start a new coordination band.

The initial implementation of TSP under these conditions did not achieve the expected benefits in terms of travel time and reliability. Trip time measurements with TSP and optimized signal coordination showed that 20-30% of trains stopped at low-volume intersections and more than 60% of trains were stopping at medium and higher-volume signals.

Metro Transit's desire to reduce travel times and improve on-time performance led them to propose a new approach to transit signal priority that would better address the challenges of light rail operation in a dense urban environment. The search for a solution focused on University Avenue in St. Paul, where a large number of closely spaced traffic signals offered the potential for significant travel time improvements for the Green Line. Known as "Predictive Priority," this approach had three main objectives that were agreed to by Metro Transit and the City of St. Paul (the owner and operator of the traffic signals):

- Maximize the opportunity for LRT to receive a green signal, based on the predicted arrival of the train at an intersection;
- Minimize disruption of signal sequence and traffic operations, especially skipping of phases;
- Avoid causing significant additional delay to road vehicle or pedestrian signal phases.

An additional objective for the new TSP strategy was to minimize additional infrastructure cost by using the robust inplace LRT detection system, communications infrastructure, and traffic signal controllers that were installed as part of the Green Line project.

Predictive Priority is based on the detection of a train at an upstream intersection, typically 25 to 60 seconds prior to arrival at the next signalized intersection. The advanced detection is received by the signal controller via the fiber optic communication network and is used to transition the signal timing – ending phases early or extending phases as needed - so that the signal will be "green" for the LRT phase at the expected time of its arrival. During the transition, the controller utilizes logic within the controller, which was developed specifically for the Green Line, to continue to serve other vehicle and pedestrian phases until the train's expected arrival at the intersection. The logic was developed in close coordination and partnership with the signal controller vendor, and required multiple iterations of testing to produce the final version that provided the desired operation of the vehicle, pedestrian, and LRT phases. Once the train arrives to a green signal indication and enters the intersection, the signal starts the clearance sequence to clear the LRT phase and transition immediately to other vehicle and pedestrian phases that have demand. If the train fails to arrive at the intersection within a set maximum time (typically 100 seconds), then the LRT phase will end and the train will proceed through the signal under the normal green band when it does arrive.

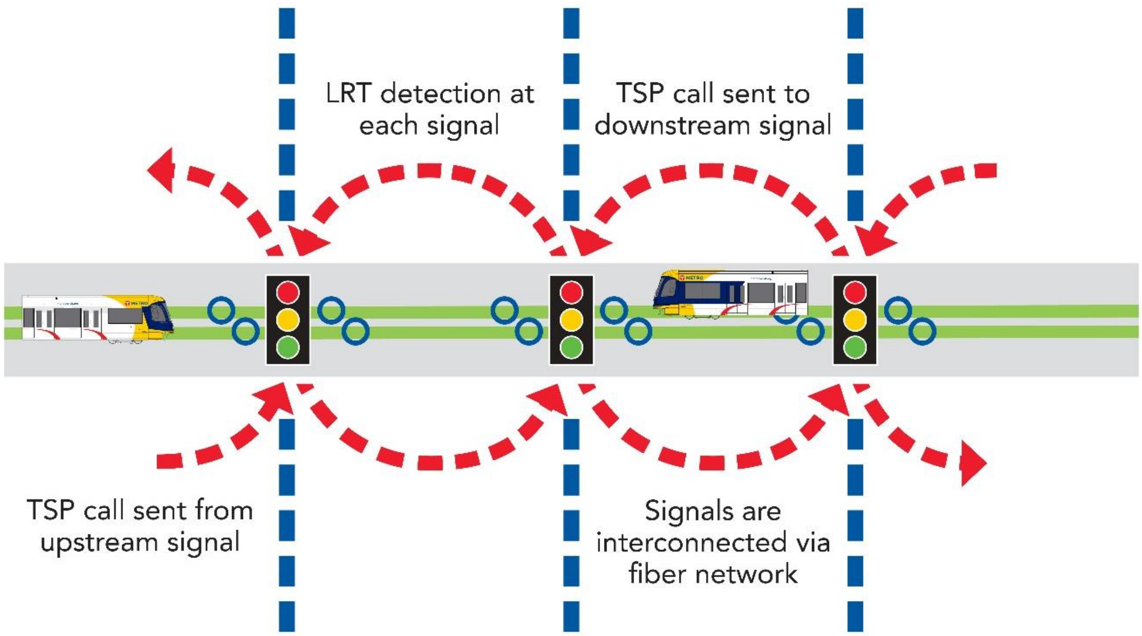

Figure 2. Schematic of Predictive Priority Detection Scheme.

Using this method of signal controller logic, vehicle and pedestrian phases are not skipped, pedestrian clearance times are always served, and vehicles and pedestrians on the cross streets do not experience long delays as they would be expected to under a preemption scheme. In addition, emergency vehicle preemption (EVP) is assigned a higher priority than LRT and is allowed to override the predictive priority at the intersection. At the same time, nearly all trains are able to progress through the predictive priority intersections without stopping.

Prior to implementing predictive priority, the in place vehicle detection was used along with new controller logic to monitor vehicle delay on the cross street and left-turn movements, as well as the pedestrian movements. The LRT detection was also used to track LRT stops and the Metro Transit Automatic Passenger Counter (APC) system was used to track train travel times through the network. This vehicle, pedestrian, and LRT data was collected for a minimum of 36 hours before and after predictive priority was implemented at each intersection. The data logs were used as a critical tool to evaluate whether the predictive priority was having the intended positive effect on LRT without negatively impacting vehicle and pedestrian delay. Extensive testing of the signal controller logic was also done with a full cabinet mock-up developed by the City of St. Paul, which was used to test numerous traffic and LRT scenarios and fine-tune the logic programming.

Data collected before and after the implementation of Predictive Priority showed that the percentage of trains stopping at predictive priority intersections was less than 5%, LRT trip times in the City of St. Paul were reduced by 10 to 15 percent, and on-time performance increased from 60% to 85% as predictive priority was implemented at 19 intersections along University Avenue from August to December 2014. Average travel times in St. Paul over this period were reduced from 34-35 minutes to less than 27 minutes, and variability in run times – a key factor in customer satisfaction – was significantly decreased. Delays for left-turning and cross-street traffic also declined, while average delays for cross-street pedestrians increased were generally similar to the before conditions. The Predictive Priority implementations were all done during the first six months of passenger service on the Green Line, and was done without any interruption to service or additional equipment or infrastructure.

Predictive Priority is a data-driven approach to transit signal priority that relies on a robust detection system for both light rail vehicles and on-street traffic. Without accurate and reliable data, the controller logic needed to optimize signal phases and minimize disruption could not be performed. The approach also requires strong integration with traffic signal controllers, and Metro Transit's experience shows the benefits of involving signal controller vendors early in the process in order to maximize the capabilities of the controller software. Finally, it is critical to identify operational priorities and understand trade-offs between competing priorities when seeking to modify the signal operations strategies to accommodate a new mode.

The authors wish to acknowledge the invaluable assistance provided by City of St. Paul Traffic Operations, Traffic Control Corporation and Metro Transit Rail Operations in implementing transit signal priority on the Green Line.

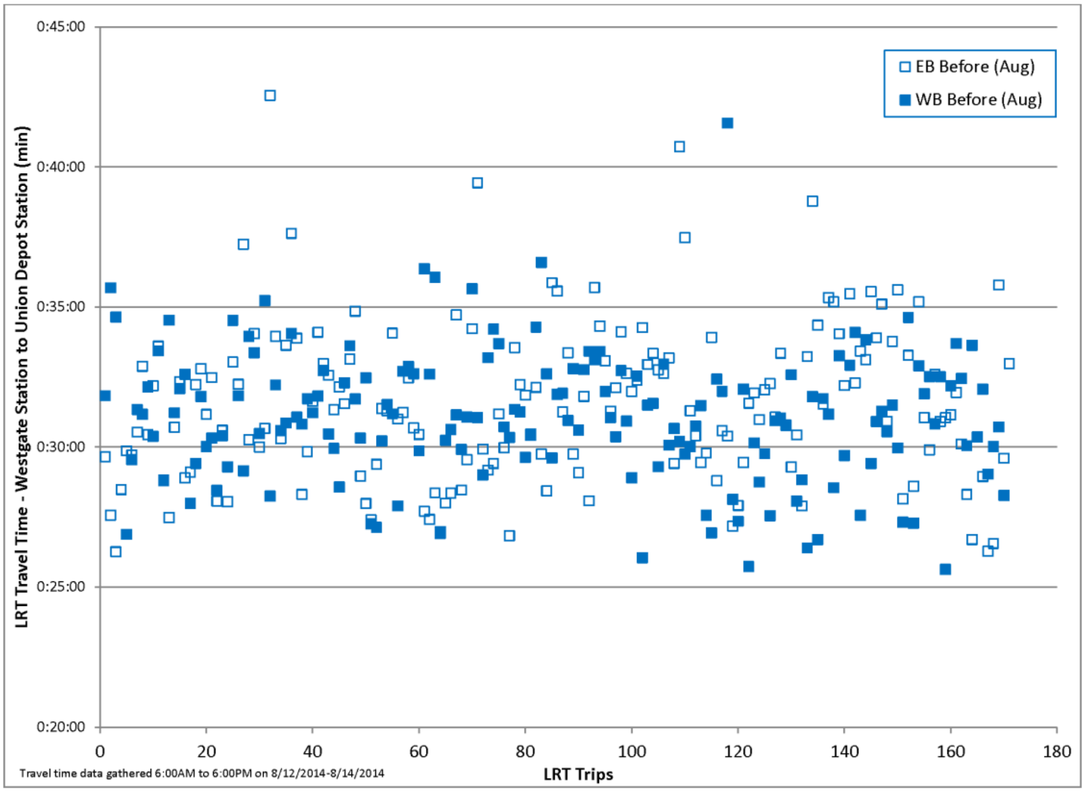

Figure 3. METRO Green Line LRT travel times before implementation of predictive priority TSP, August 12-14, 2014 (n=171 eastbound, 169 westbound trips).

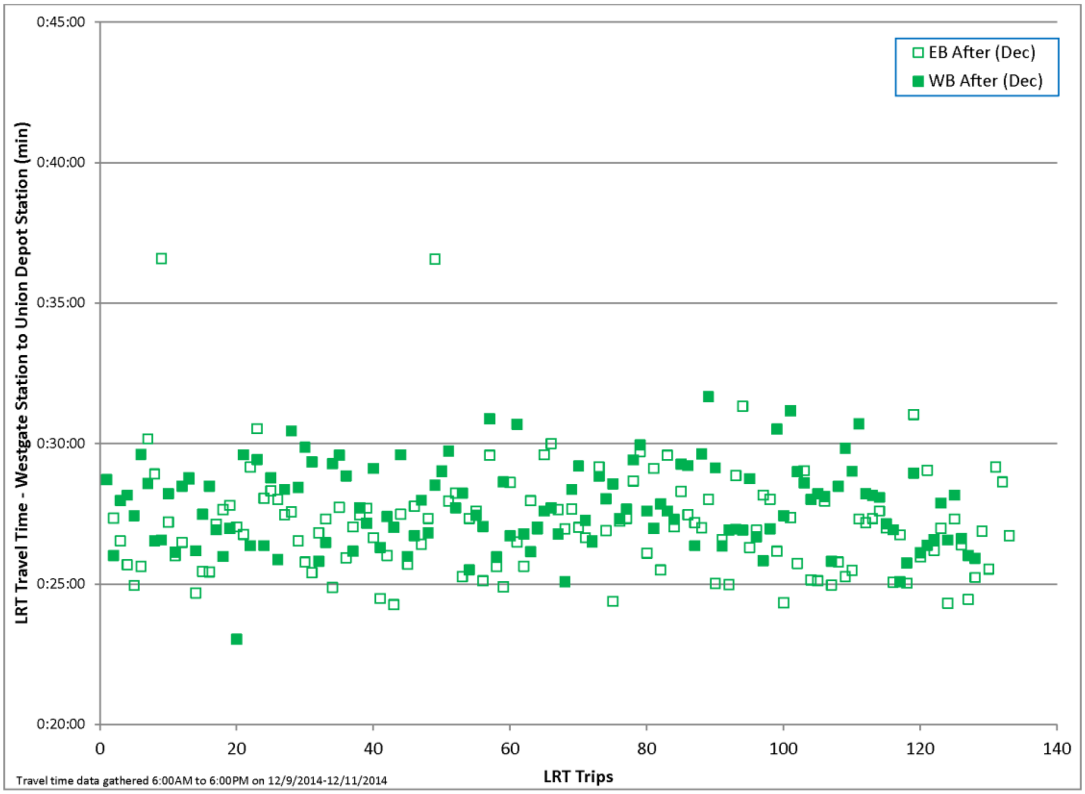

Figure 4. METRO Green Line LRT travel times after implementation of predictive priority TSP, December 9-11, 2014 (n=132 eastbound, 128 westbound trips).

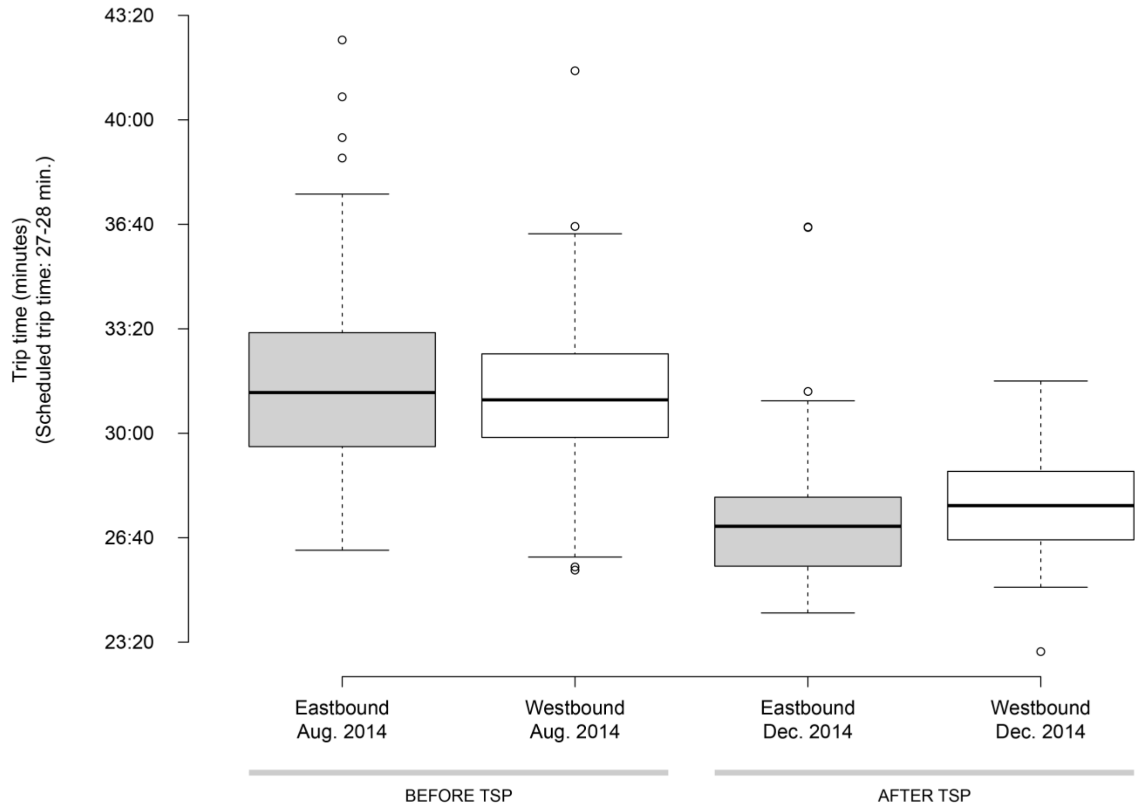

Figure 5. Comparison of METRO Green Line travel times before and after implementation of predictive priority TSP. Center lines show the medians; box limits indicate the 25th and 75th percentiles as determined by R software; whiskers extend 1.5 times the interquartile range from the 25th and 75th percentiles, outliers are represented by dots. n = 171, 169, 132, 128 sample points.